

Space Weather 101



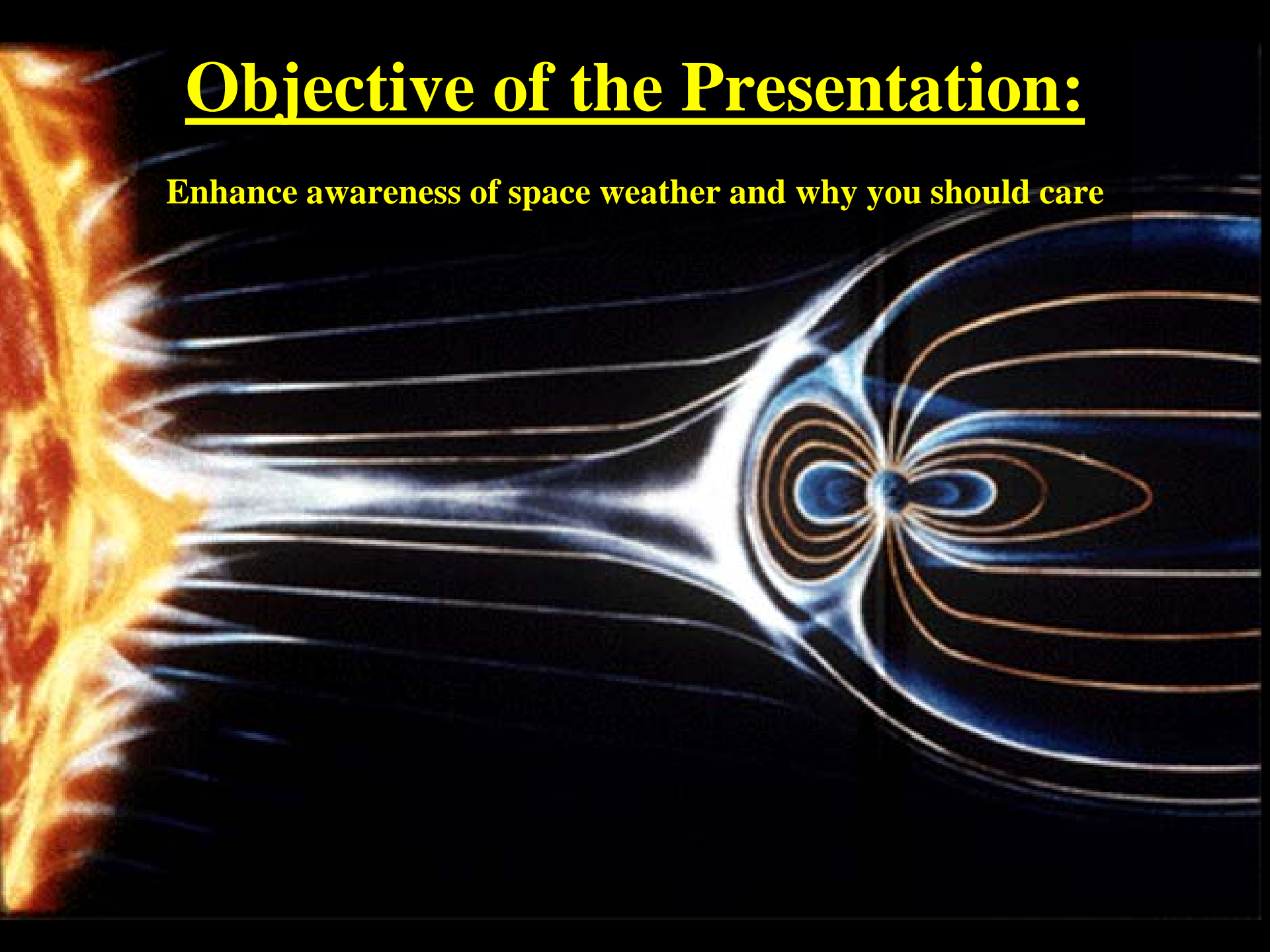
Dr. Dennis Gallagher

NASA Marshall Space Flight Center

Dennis.Gallagher@nasa.gov

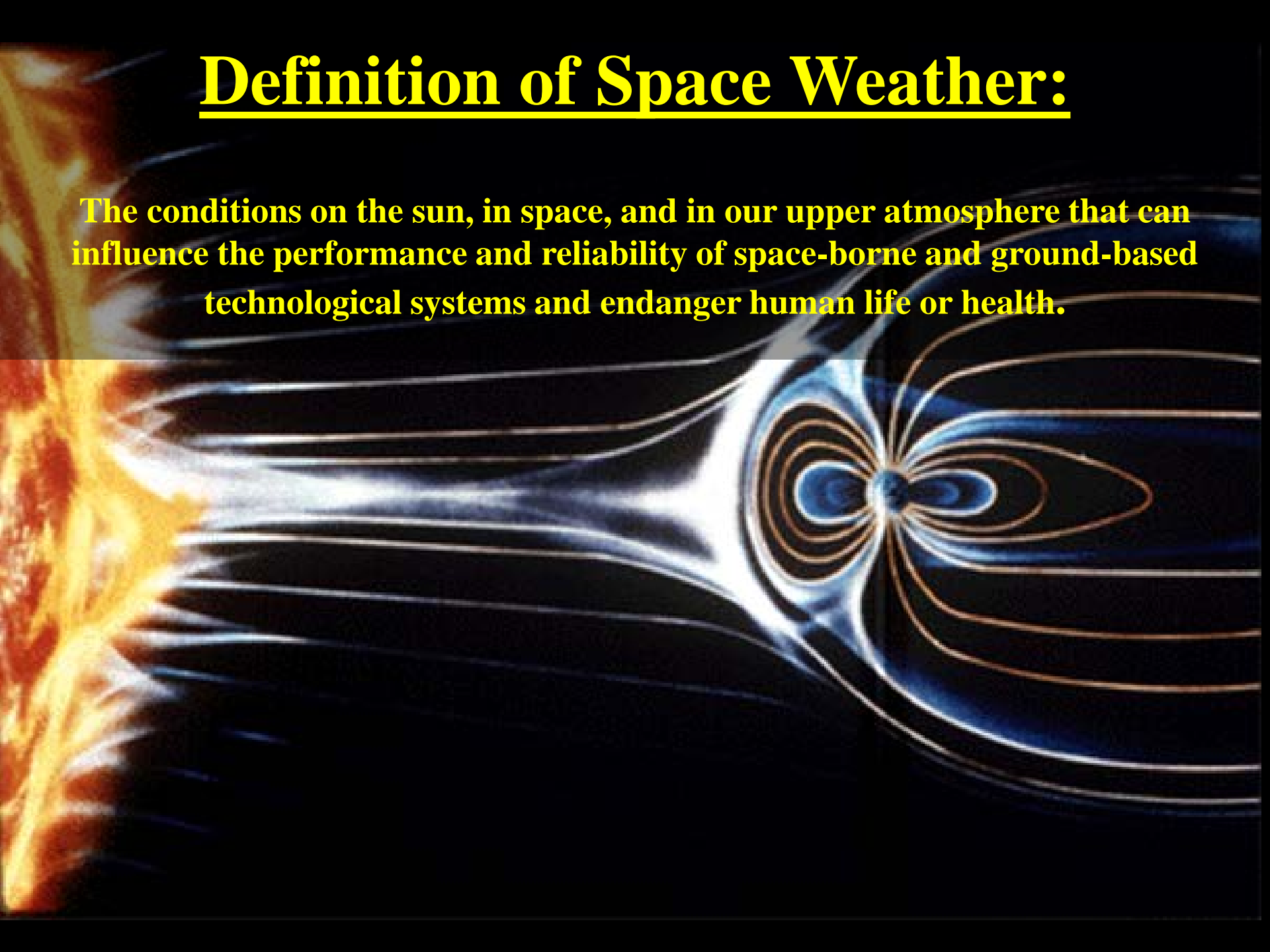
Objective of the Presentation:

Enhance awareness of space weather and why you should care



Definition of Space Weather:

The conditions on the sun, in space, and in our upper atmosphere that can influence the performance and reliability of space-borne and ground-based technological systems and endanger human life or health.



What does Weather mean to you?

Weather on Earth



What does Weather mean to you?

Weather on Earth



Weather on Earth

What does Weather mean to you?

Inspiration



Weather on Earth

What does Weather mean to you?



Weather on Earth

What does Weather mean to you?



Threat at Home

Weather on Earth

What does Weather mean to you?



Regional Threat



Weather on Earth

What does Weather mean to you?



Familiarity from Space

NASA



What does Weather mean to you?

Weather on Earth



- Precipitation
- Light Displays
- Power of Nature
- Societal Danger



Weather in Space?



Weather in Space?

- Precipitation



Weather in Space?



- **Precipitation**
- **Light Displays**

Weather in Space?



- **Precipitation**
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- **Power of Nature**

Weather in Space?



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- **Societal Danger**

Weather in Space?



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Where is the Shock and Awe?

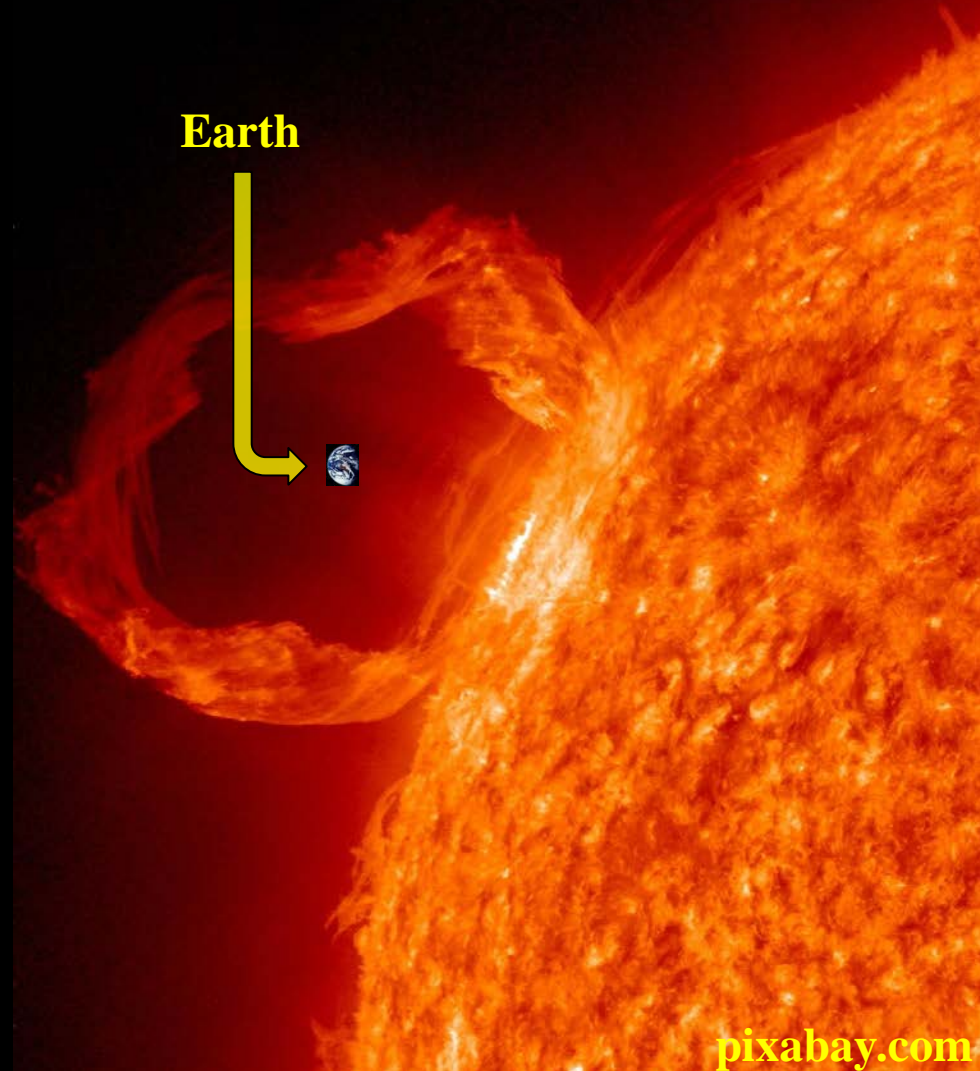
Start at the Sun

Flare: explosive brightening or

Coronal Mass Ejection:

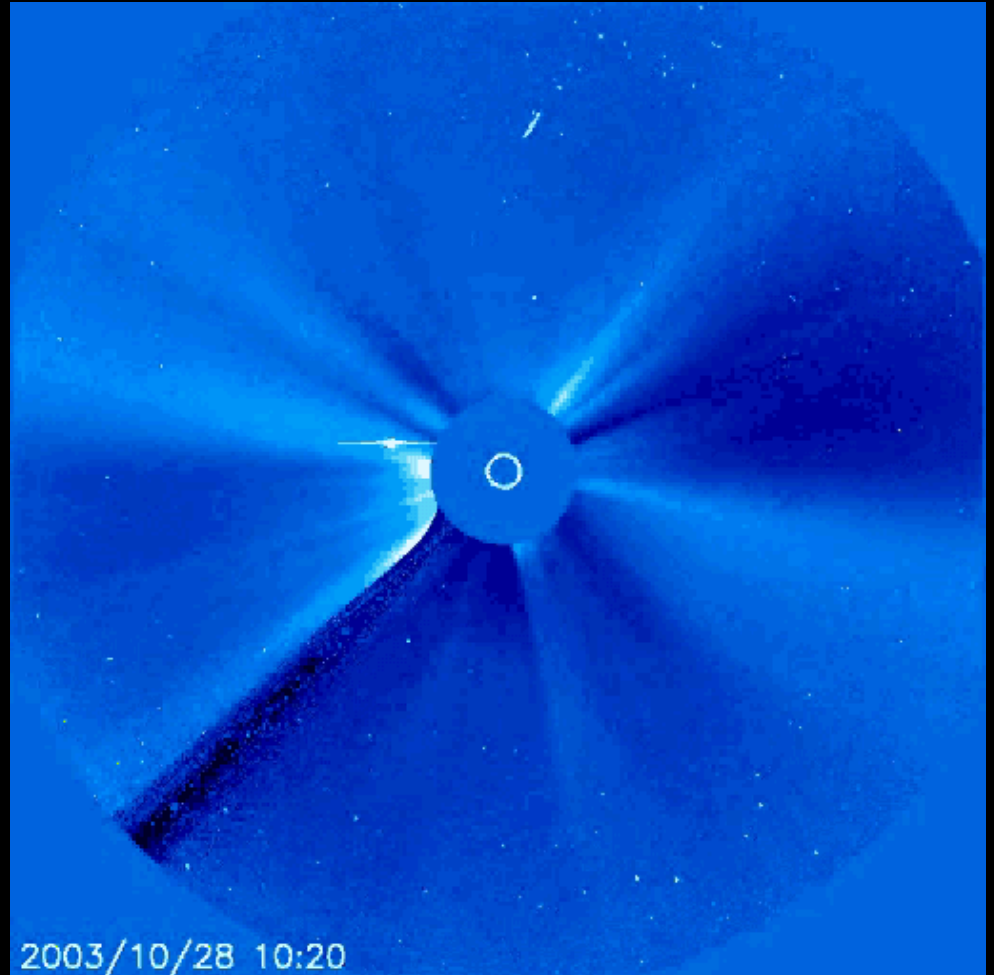
Violent release of as much as a billion tons of matter (36 moderate sized mountains).

Can be equivalent of 40 billion Hiroshima-sized atomic bombs (enough to destroy everything on Earth's surface more than 900 times).

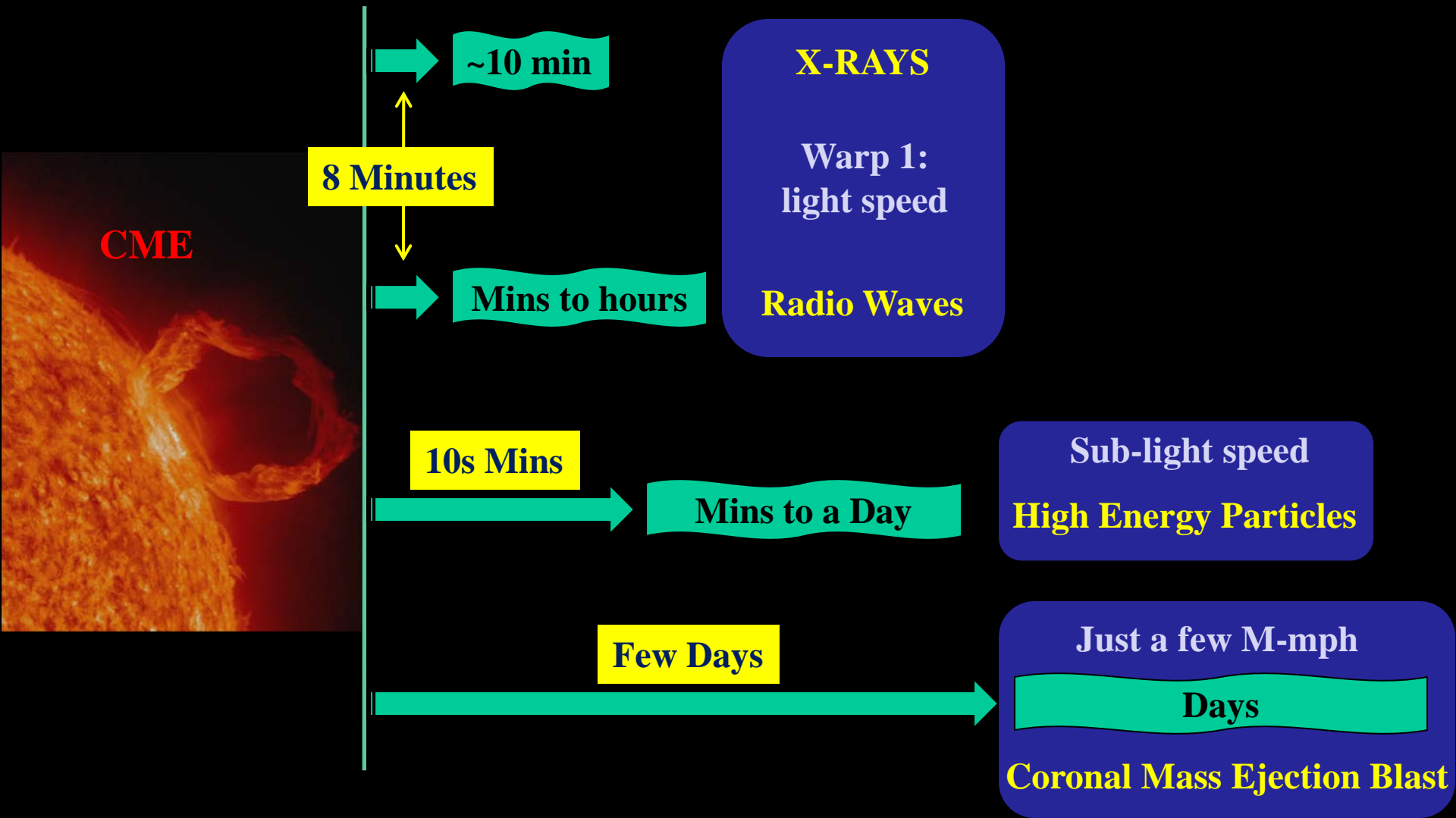


Weather at the Sun or Elsewhere Means There are Events

- **What do you see?**
- **Near the Sun?**
- **Far from the Sun?**

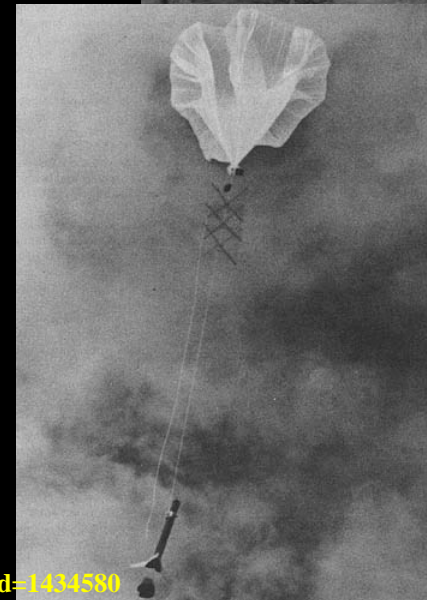
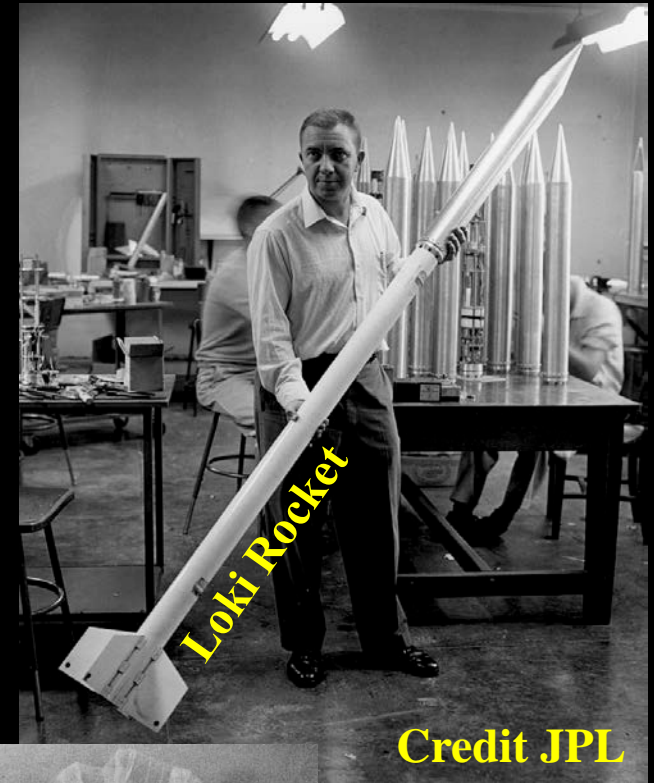


Time Scale for Solar Effects at Earth



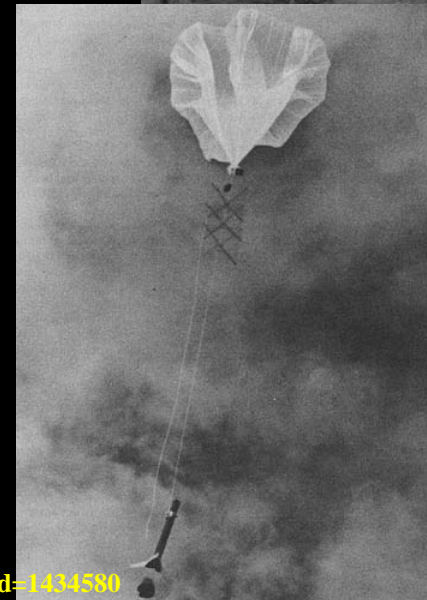
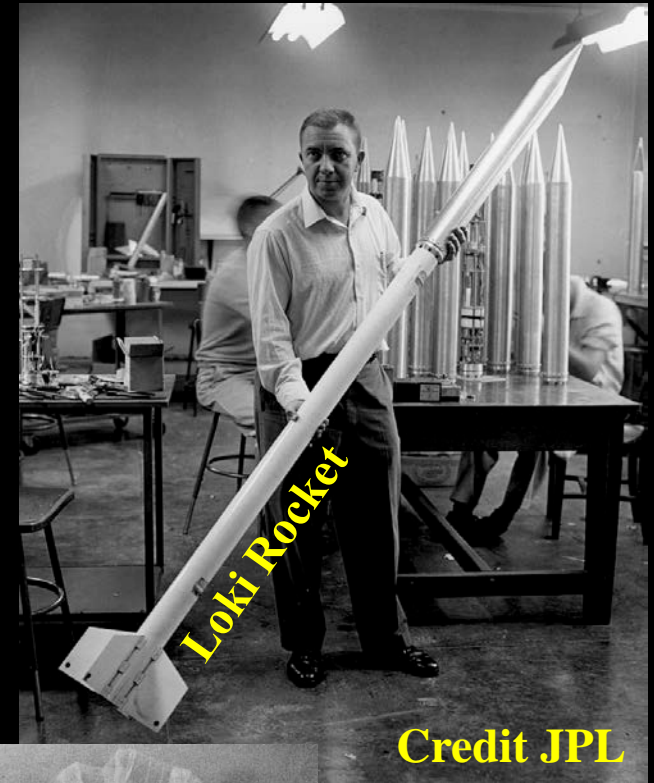
Cosmic Radiation

- **Radiation:** electromagnetic waves and particles
- **Ionizing radiation:** more dangerous
- **Physical amount:** radiation flux
- **Biological effect:** much more complex



Cosmic Radiation

- 1 rem = 0.01 Sievert (current SI unit)
- 1 millirem = medical x-ray or background
- 1 rem → 0.05% chance of cancer
- 100 rem → over short time, acute radiation syndrome
- Rad or Sieverts are better correlated to exposure symptoms



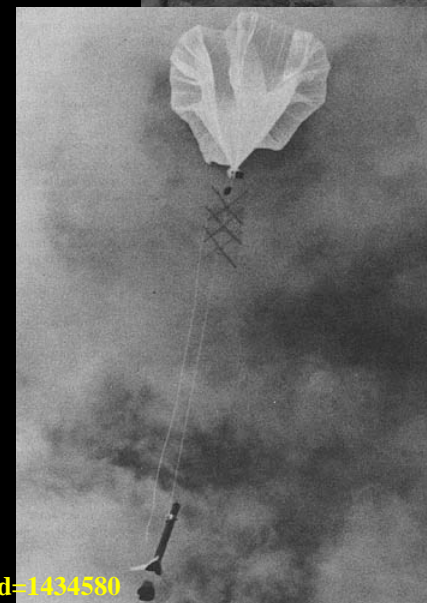
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Credit JPL

**Surface of Mars!
10-20 rem/year**



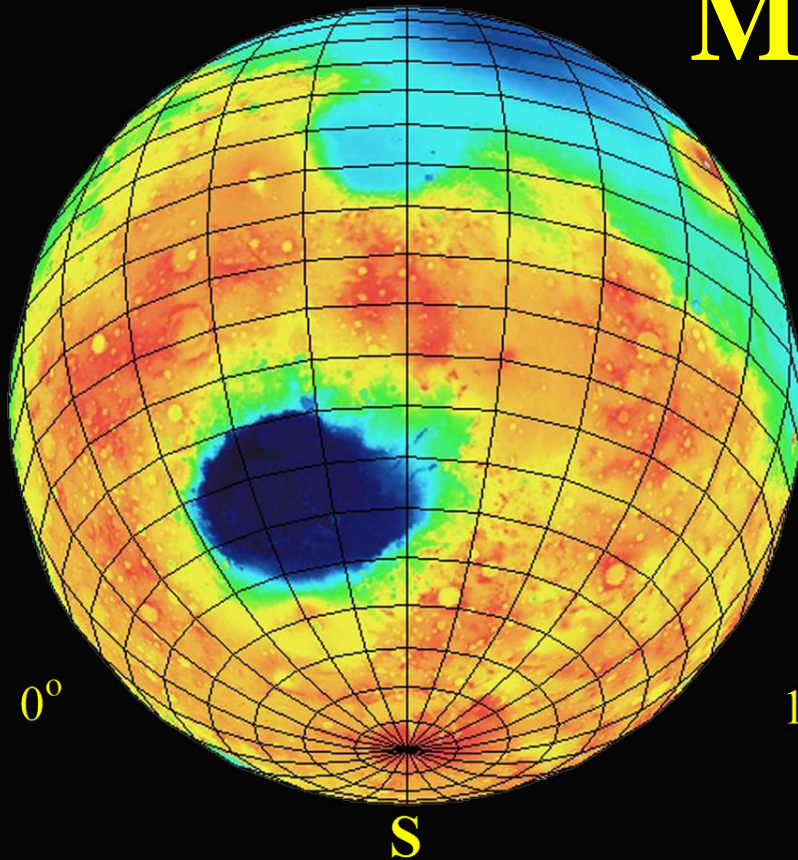
Cosmic Ray Environment

Dose Equivalent Values (rem/yr)

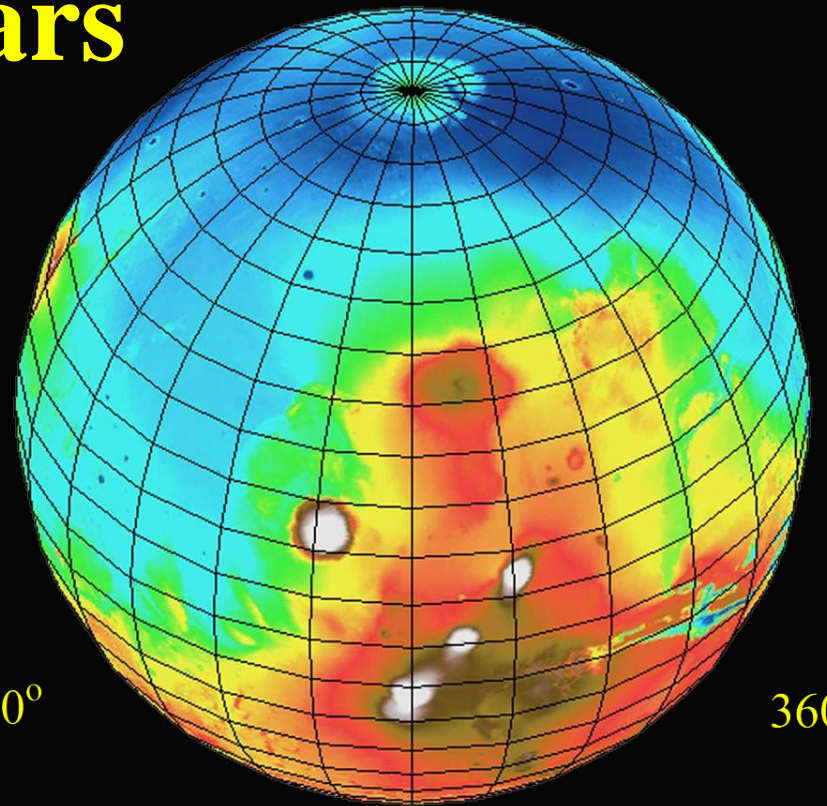


Mars

N



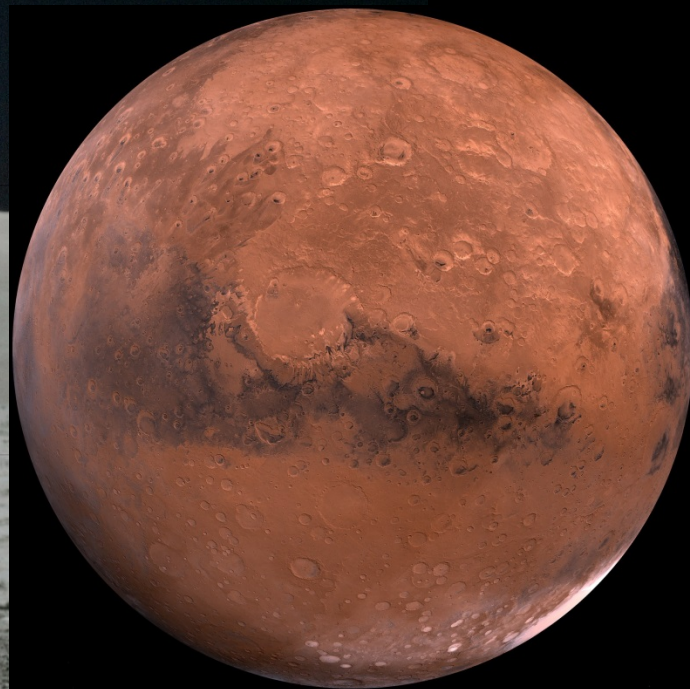
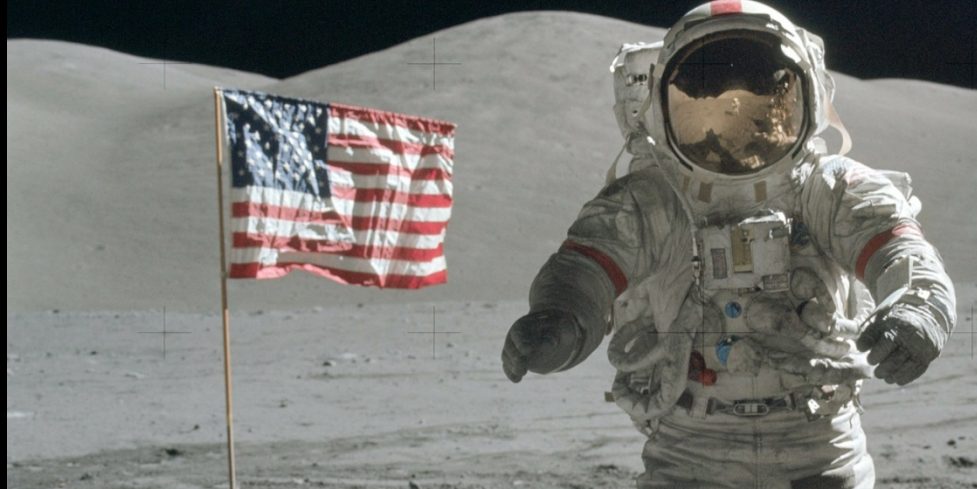
180°



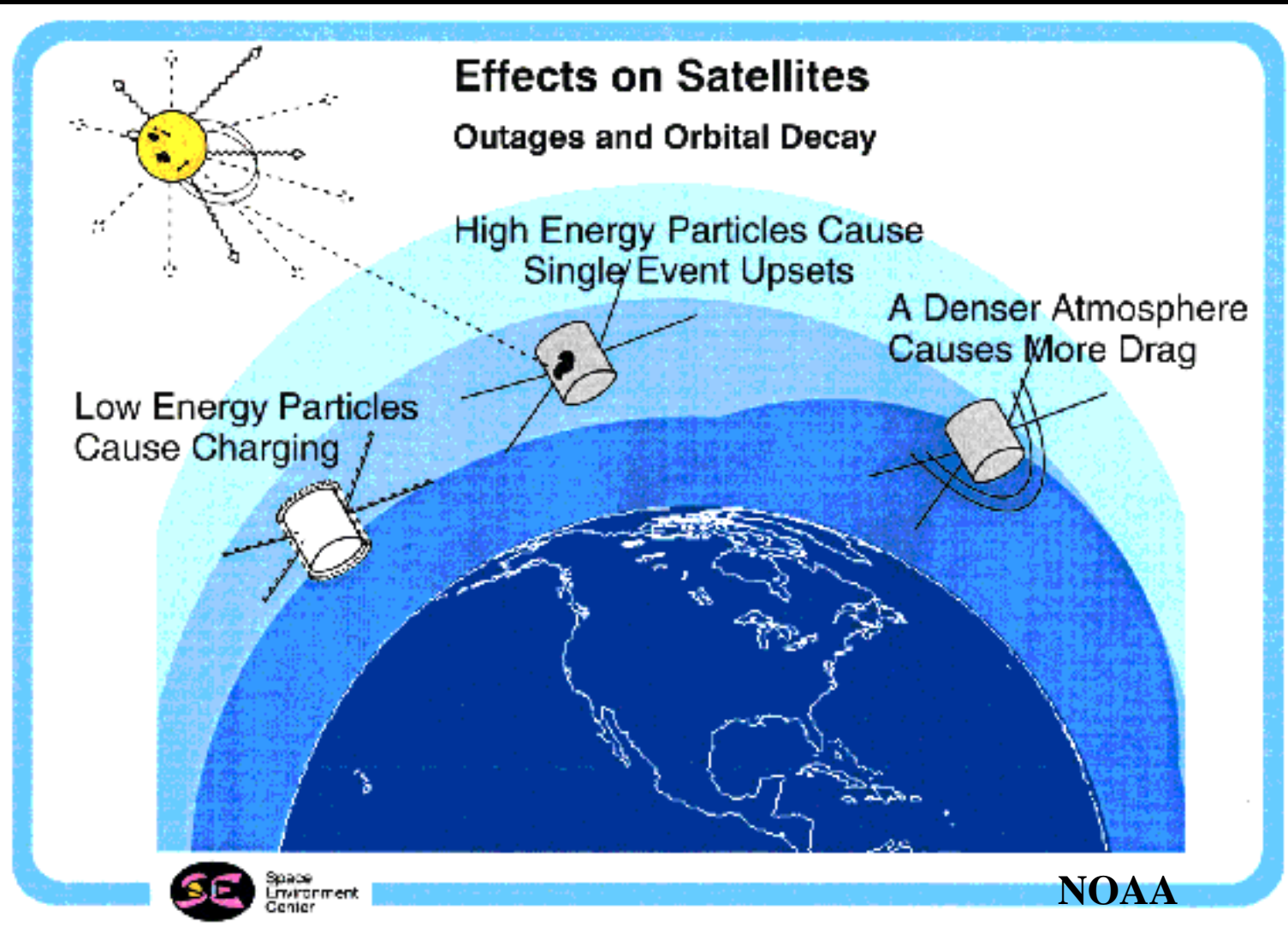
360°

Credit NASA

Hazards to Humans in Space

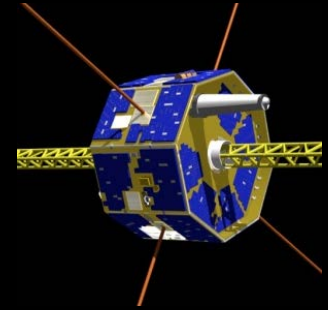


Satellite Hazards



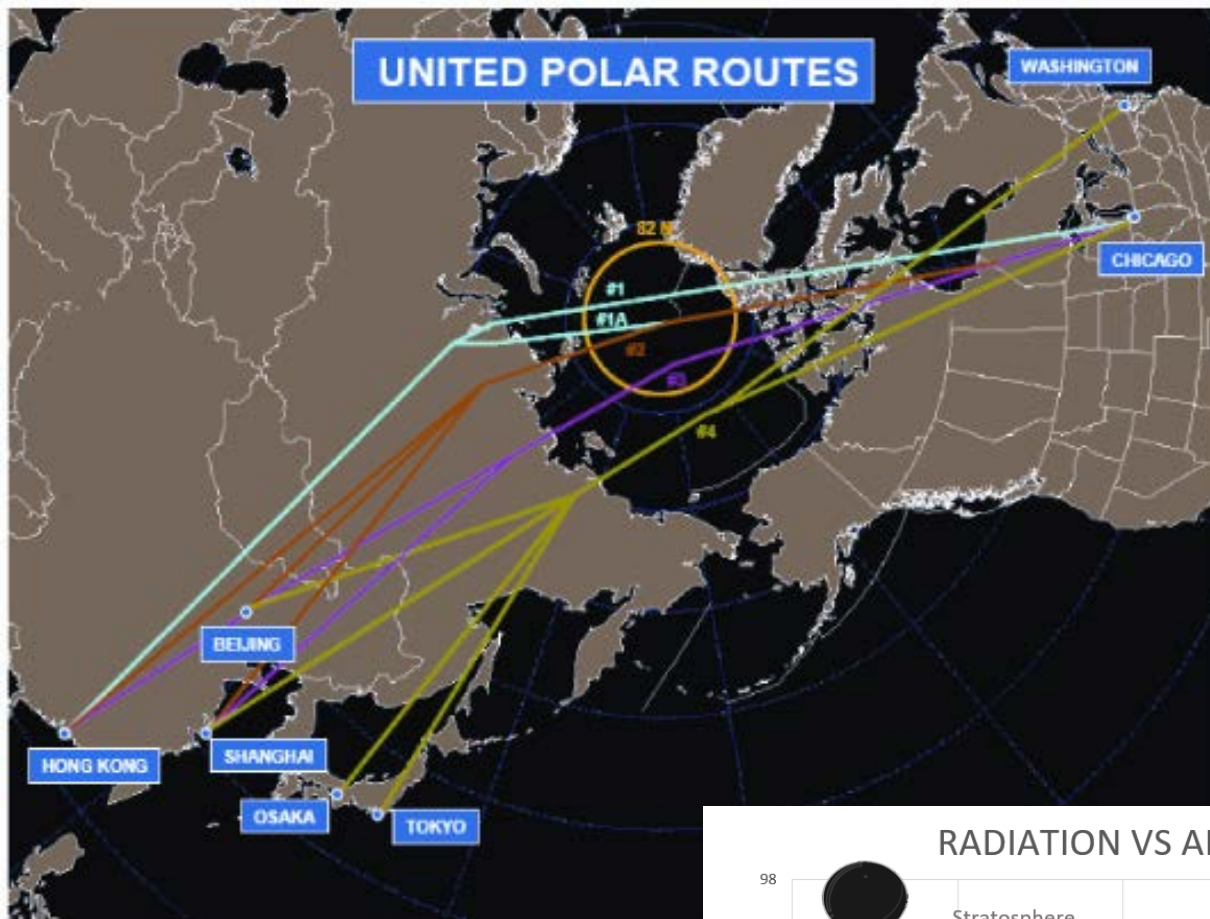
Risks for Electronics

- In space single event upsets (SEUs) cause satellite control errors, risking damage or loss
- In aircraft SEUs cause upsets of about 1 per 200 hours of operation measured on a Boeing 777 autopilot: (designed for 1:1 million); pacemakers have been used to measure SEUs in commercial aircraft
- On the ground SEUs are thought to have caused power losses in German high-speed trains in the 1990's from cosmic radiation



pixabay.com

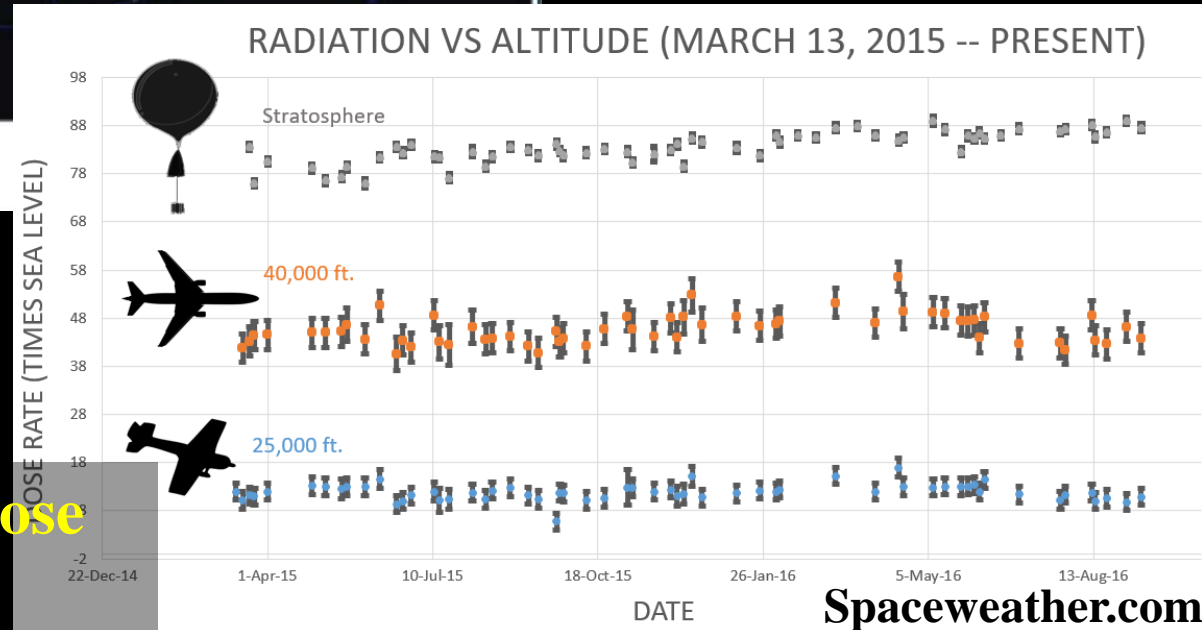




**Transpolar
Flights and
cosmic
radiation risks
are increasing**

Credit: Mike Stills, United

**From the American
Meteorological Society &
SolarMetrics Policy Workshop
Report March 2007**

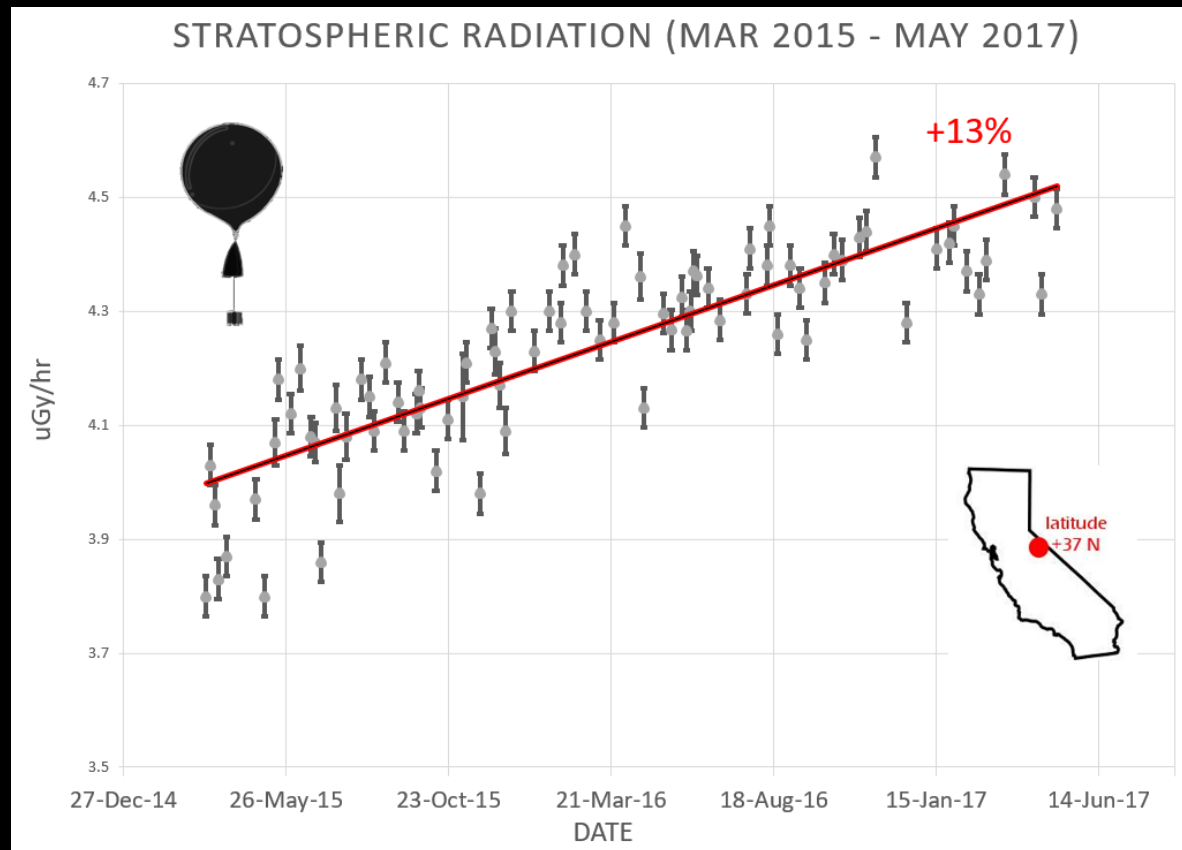


**Max permissible mean dose
rate limit: 7.5 mSv/hour**

Students of Earth to Sky Calculus

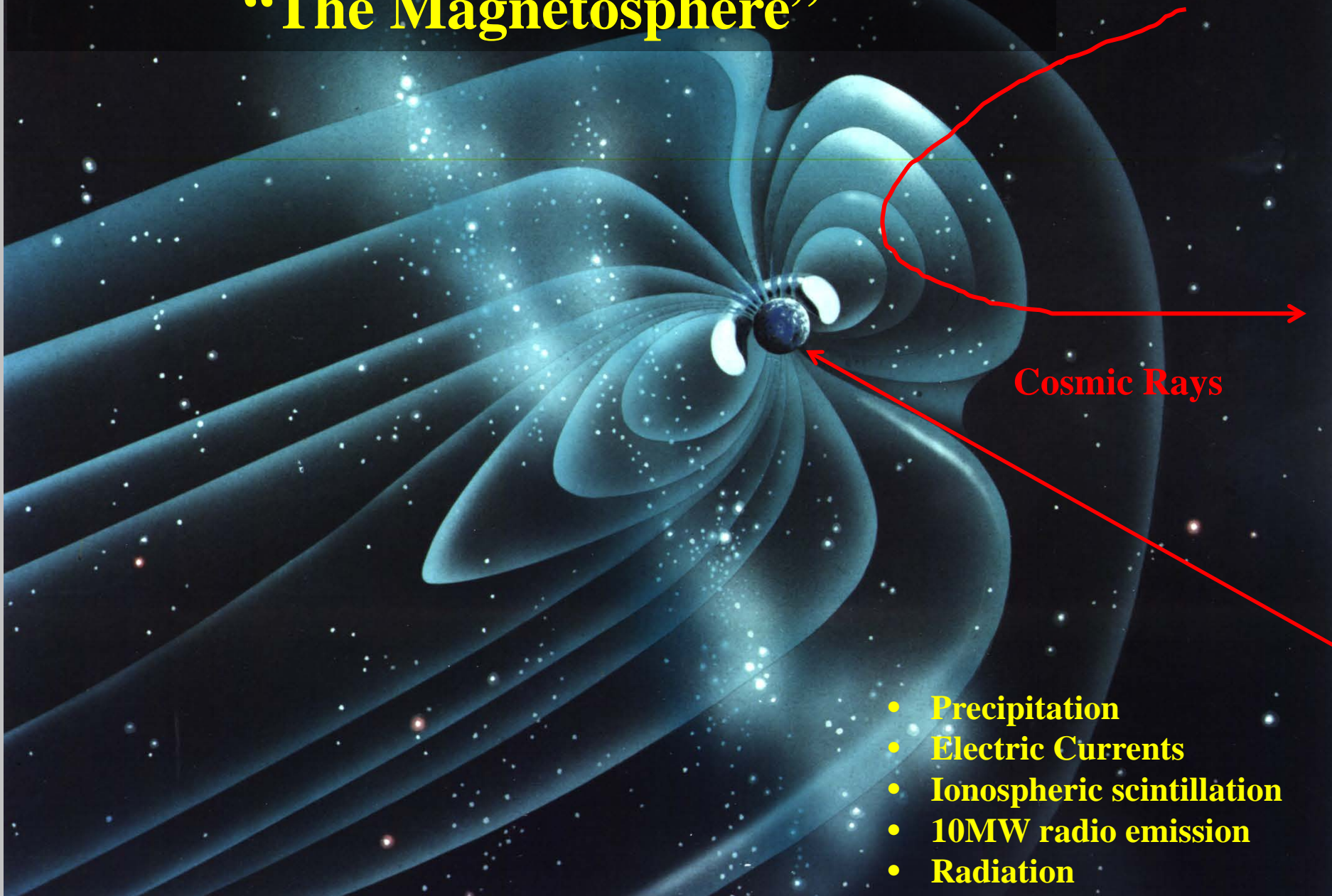
@Spaceweather.com by Dr. Tony Phillips

- **3-years of balloon results**
- **Cosmic radiation comes from outside the solar system.**
- **Falling solar cycle lets more reach Earth.**
- **Stay tuned for continued reporting in future months...**



Earth's Magnetic Environment

"The Magnetosphere"



Cosmic Rays

- Precipitation
- Electric Currents
- Ionospheric scintillation
- 10MW radio emission
- Radiation

Aurorae: the greatest show on Earth...

Precipitating energetic particles

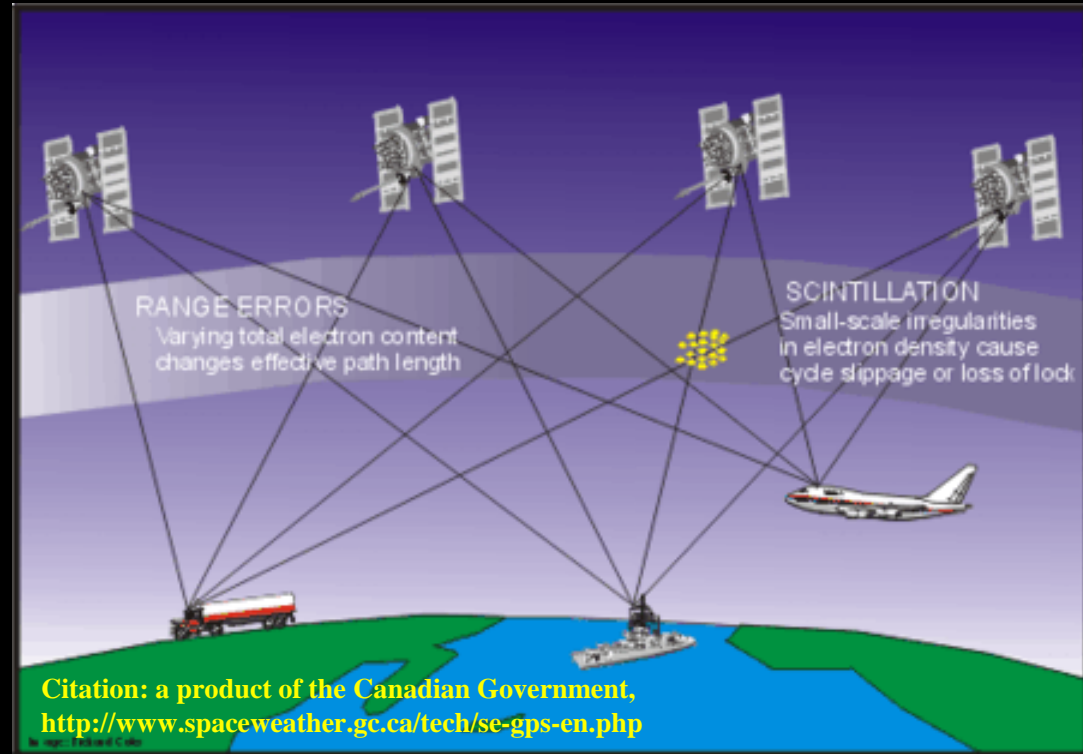


Disruption of:

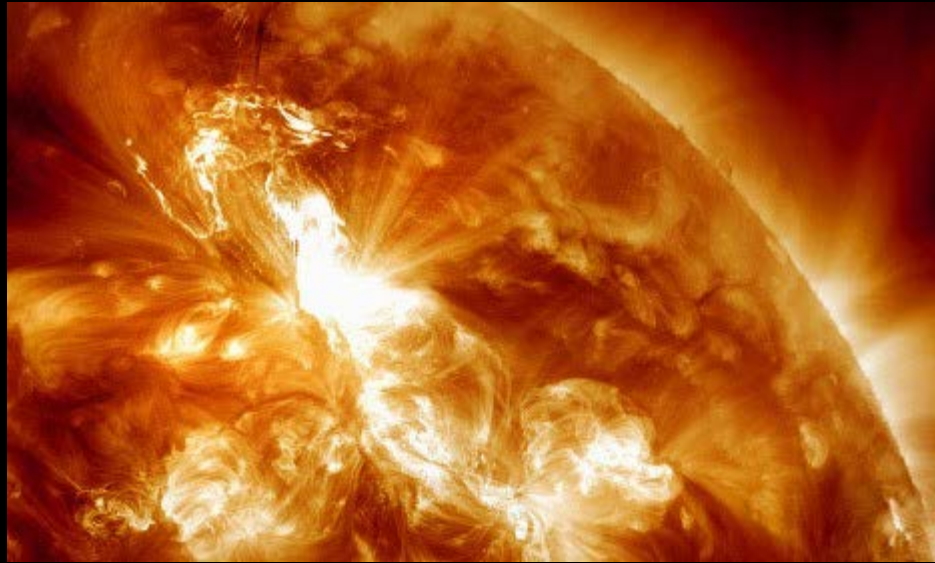
HF Communication



Navigation



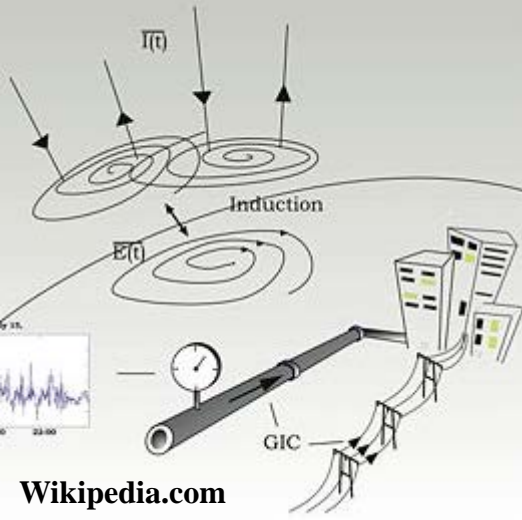
'Solar storm' grounds Swedish air traffic



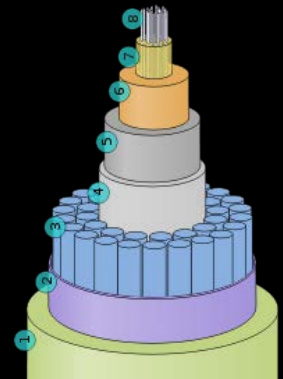
Reported in the December 1, 2015 issue of “The Local Europe AB” an English version of Sweden’s news:

Planes were grounded at some of Sweden's busiest airports on Wednesday afternoon because of a "solar storm" interfering with air traffic control radar systems, authorities said.

Ground Induced Currents (GIC)



- Railroads:
 - Sweden in 1982, railway signals failed to switch correctly
 - Norway in 2000, 19 lives were lost
- Deep Sea Cables:
 - Space Weather can generate hundreds to thousands of volts



Pipeline Corrosion



To Fight
Corrosion

Applied
Voltage

-

+

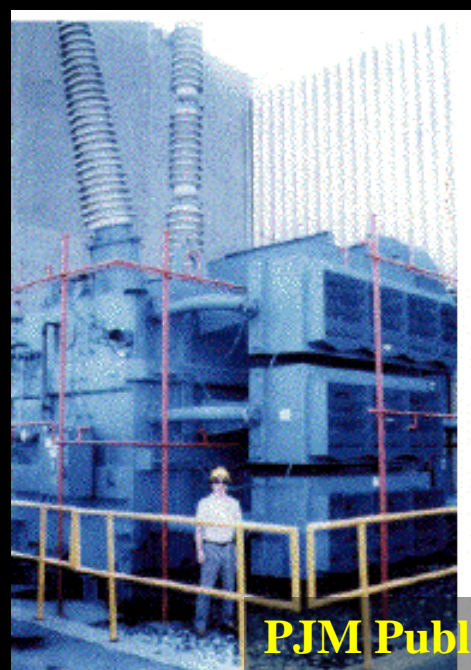
March 13, 1989 Electrical Power Disruption Due to Induced Electric Currents



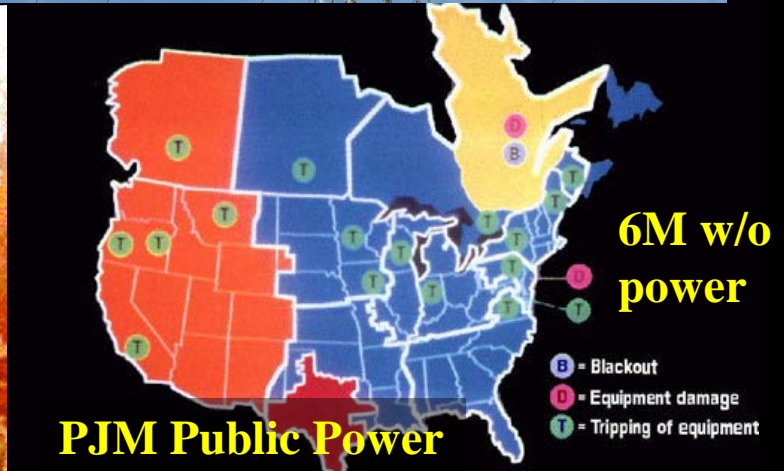
shutterstock pixabay.com



**PJM Step Up Transformer-
Damage from space storm**











PJM Public Power



PJM Public Power

Atmospheric storms are measured. Space storms are too.

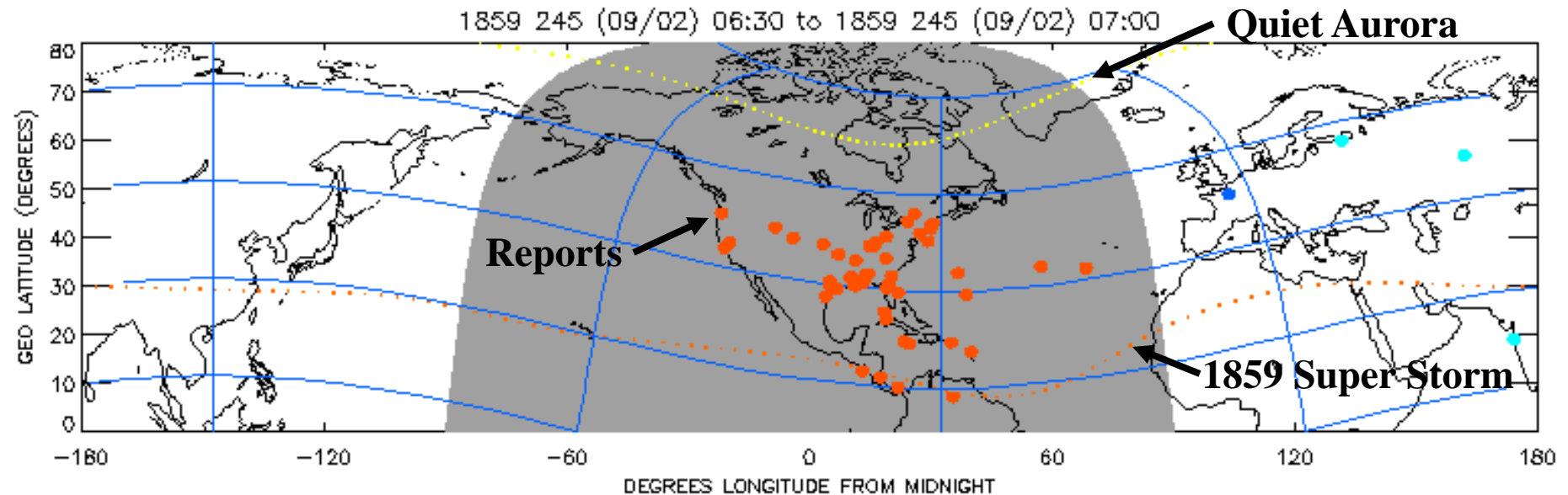


Space Storm	Minor  Extreme
Solar Flares	B  C  M  X
Solar Radiation	S1  S5
Radio Blackouts	R1  R5
Geomagnetic Storms	G1  G5

pixabay.com

September 2, 1859 Event

3X recent storm strength / 1/3 strongest ever

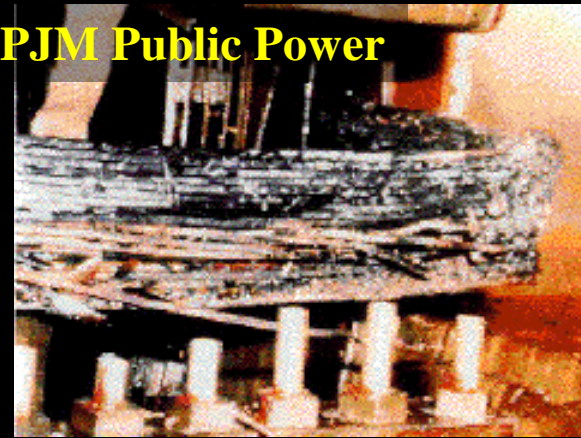


- Messenger (deck log: Lat. 49°) “we witnessed the most magnificent display of the aurora boreales (sic) imaginable ... the whole firmament was a blaze of Crimson shooting up from all points of the compass but the most splendid from the South W. I have not the language to describe it”

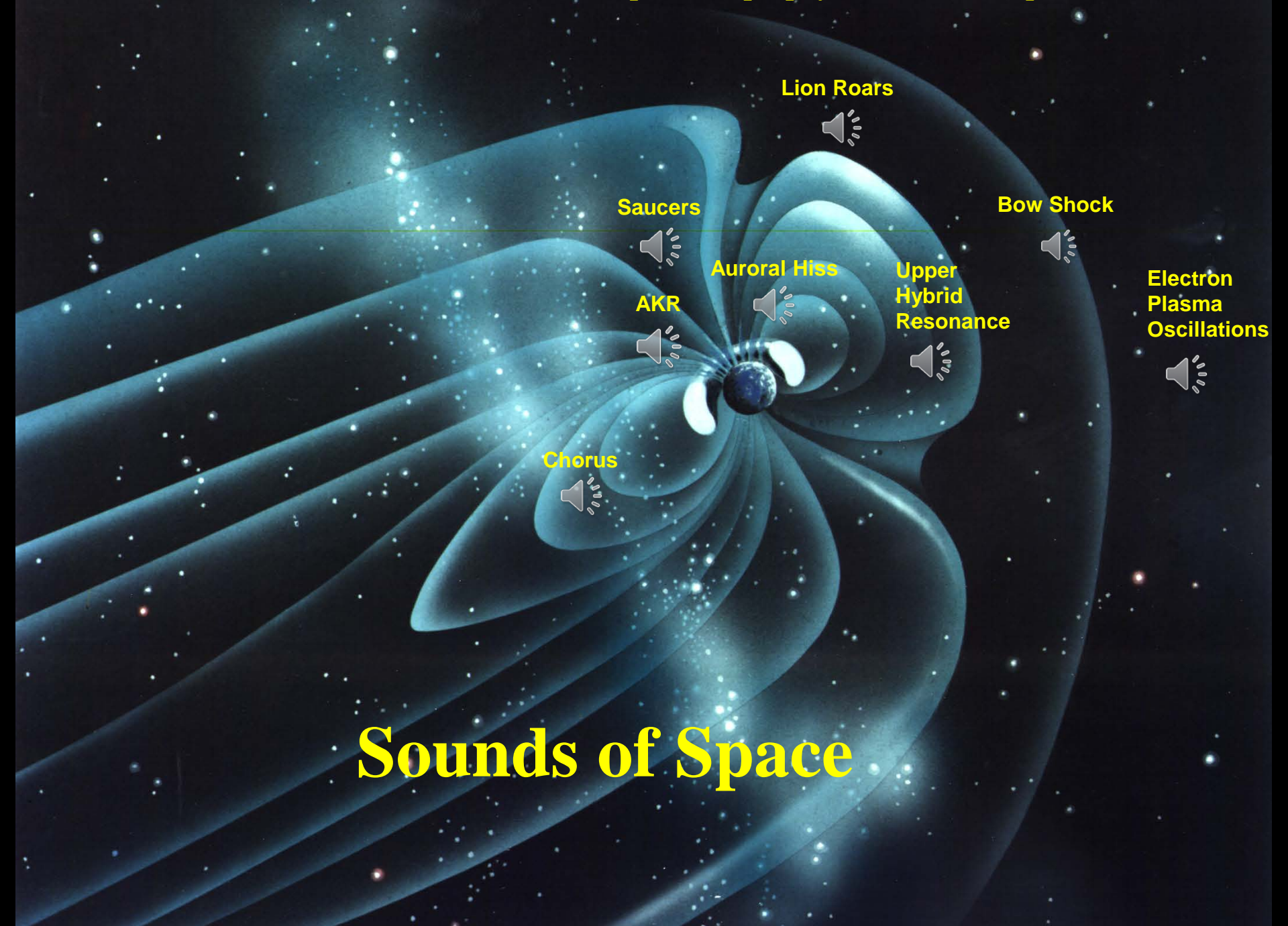
Courtesy James L. Green, NASA/GSFC

Weather in Space

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Shock and Awe!



Lion Roars



Saucers



Auroral Hiss



AKR



Chorus



Upper Hybrid Resonance



Bow Shock



Electron Plasma Oscillations



Sounds of Space